

# **Otter Brook Lake Hydropower Study Keene, New Hampshire**



**US Army Corps  
of Engineers**  
New England Division

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## FOREWORD

This report presents the results of a reconnaissance study of the feasibility of adding hydropower facilities to the existing Corps of Engineers flood control project located on Otter Brook in Keene, New Hampshire.

Using current Water Resources Council Principles and Guidelines criteria, the addition of hydropower facilities at Otter Brook Lake has been found to be economically justified. A 117 kw installation utilizing a mini-submersible turbine-generator unit installed in a new weir upstream of the center flood control gate could generate 499,500 kwh annually at a cost of approximately 72 mills per kilowatt-hour. Implementation of this plan would require a seasonal increase in the reservoir pool of 12 feet to elevation 715 feet NGVD for hydropower operations.

Funding constraints have limited the scope of this study effort to gathering baseline data from existing literature. Only run-of-river alternatives were considered. More comprehensive plans involving storage for hydropower were not considered within the scope of study. No detailed hydrologic, hydraulic or reservoir regulation studies were performed. Design and cost estimates proposed for this report are of reconnaissance level of detail.

Detailed studies regarding social or environmental acceptability of the proposal have not been undertaken. Similarly, environmental assessments and issues have not been considered. These and other issues will be investigated together with plans of development as this study progresses.

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## INTRODUCTION

### PURPOSE AND AUTHORITY

This is a reconnaissance report to determine the feasibility of adding hydroelectric generating facilities to the Corps of Engineers flood control project at Otter Brook Lake in Keene, New Hampshire on Otter Brook. Authority for this study is contained in Section 216 of Public Law 91-611 (the River and Harbor Act of 1970):

Section 216. The Secretary of the Army, acting through the Chief of Engineers, is authorized to review the operation of projects the construction of which has been completed and which were constructed by the Corps of Engineers in the interest of navigation, flood control, water supply, and related purposes, when found advisable due to significantly changed physical or economic conditions, and to report thereon to Congress with recommendations on the advisability of modifying the structures or their operation, and for improving the quality of the environment in the overall public interest.

### SCOPE OF STUDY

The principal reason for this limited reconnaissance investigation is to determine whether any economically feasible hydropower development could be undertaken at Otter Brook Lake. Baseline environmental, recreation, social and cultural conditions in the study area have been identified. Due to the time and funding constraints only three alternative plans for development were considered at this time. If the study is continued into the feasibility investigation stage, several other alternatives will be formulated and evaluated.

### STUDY PARTICIPANTS AND COORDINATION

This study was conducted by the New England Division, Corps of Engineers. Informal telephone communications and meetings with various State and local interests provided useful data. The Federal Energy Regulatory Commission (FERC) also provided input to this report.

### REPORT AND STUDY PROCESS

This reconnaissance report is the product of the initial study stage which the Corps utilizes for planning potential projects. In subsequent study stages, alternative plans will be formulated and evaluated and if an implementable plan of Federal interest is identified, it will be submitted to Congress for authorization and construction.

The multilevel planning framework utilized by the Corps in its studies is designed to insure that a complete and systematic evaluation is accomplished. Problems, needs, concerns and opportunities are all identified and addressed through the study process. Plans are formulated

and evaluated and social, cultural, environmental and economic impacts are assessed. Public input is sought throughout the study and efforts are made to keep the public informed on the study progress, in order to surface any pertinent issues which could significantly affect the findings. The approaches used for this study are consistent with the "Principles and Guidelines" as amended by the President's Cabinet Council on Water Resources and Environment and the National Environmental Policy Act of 1969.

As the study progresses, detailed data will be collected and developed for the formulation and assessment of alternatives until it becomes possible to identify the best alternatives from both environmental and economic perspectives. Ultimately, using the study findings and public involvement, a plan warranting Federal interest and the investment of public funds may be identified.

#### OTHER STUDIES

In February 1980, the Federal Energy Regulatory Commission (FERC) issued preliminary permit No. 2819 to the Vermont Electric Cooperative, Inc., (VEC) to investigate the feasibility of developing hydroelectric generating facilities at the existing Otter Brook Dam.

The VEC received a feasibility study loan under the Title IV program sponsored by the Department of Energy to evaluate the financial feasibility of a proposed project and identify potential constraints that could inhibit development at Otter Brook Lake Dam. The study was completed in July 1982. The study results indicated that the site was technically feasible but not considered economically feasible by VEC for development of hydroelectric facilities. VEC allowed its permit to expire in February 1983.

There are no other known hydropower studies at Otter Brook Dam. The Corps of Engineers completed a Master Manual of Reservoir Operation in January 1972.

#### PROBLEM IDENTIFICATION

##### NATIONAL AND REGIONAL OBJECTIVES

The primary purpose of the hydropower addition under consideration is to reduce regional (and national) dependence on oil for electrical energy generation. Currently, approximately 60 percent of New England's electrical energy is produced by oil-fired generating plants. A hydropower addition to the Otter Brook Lake project would displace oil-generated electrical energy, thereby reducing dependence on oil. Any hydropower plans developed would have to be technically, environmentally, economically, and socially acceptable.

## EXISTING CONDITIONS IN THE STUDY AREA

### Physical Setting

Otter Brook Lake is a flood control project owned and operated by the U.S. Army Corps of Engineers. The project is located on Otter Brook, a tributary to the Ashuelot River, in the city of Keene, New Hampshire. The dam is located 2.7 miles above the confluence of Otter and Minnewawa Brooks. A vicinity map is shown on Figure 1.

The important physical components of the Otter Brook project consist of a rolled earth dam with rock slope protection, chute spillway, outlet works, storage for flood control and facilities for recreational purposes. Pertinent data on the Otter Brook Lake project is summarized in Table 1.

TABLE 1

#### PERTINENT DATA - OTTER BROOK DAM

Location: Otter Brook, Keene, Cheshire County, New Hampshire

Drainage Area: 47.2 square miles

Storage Use: Flood control and recreation

Reservoir Storage:

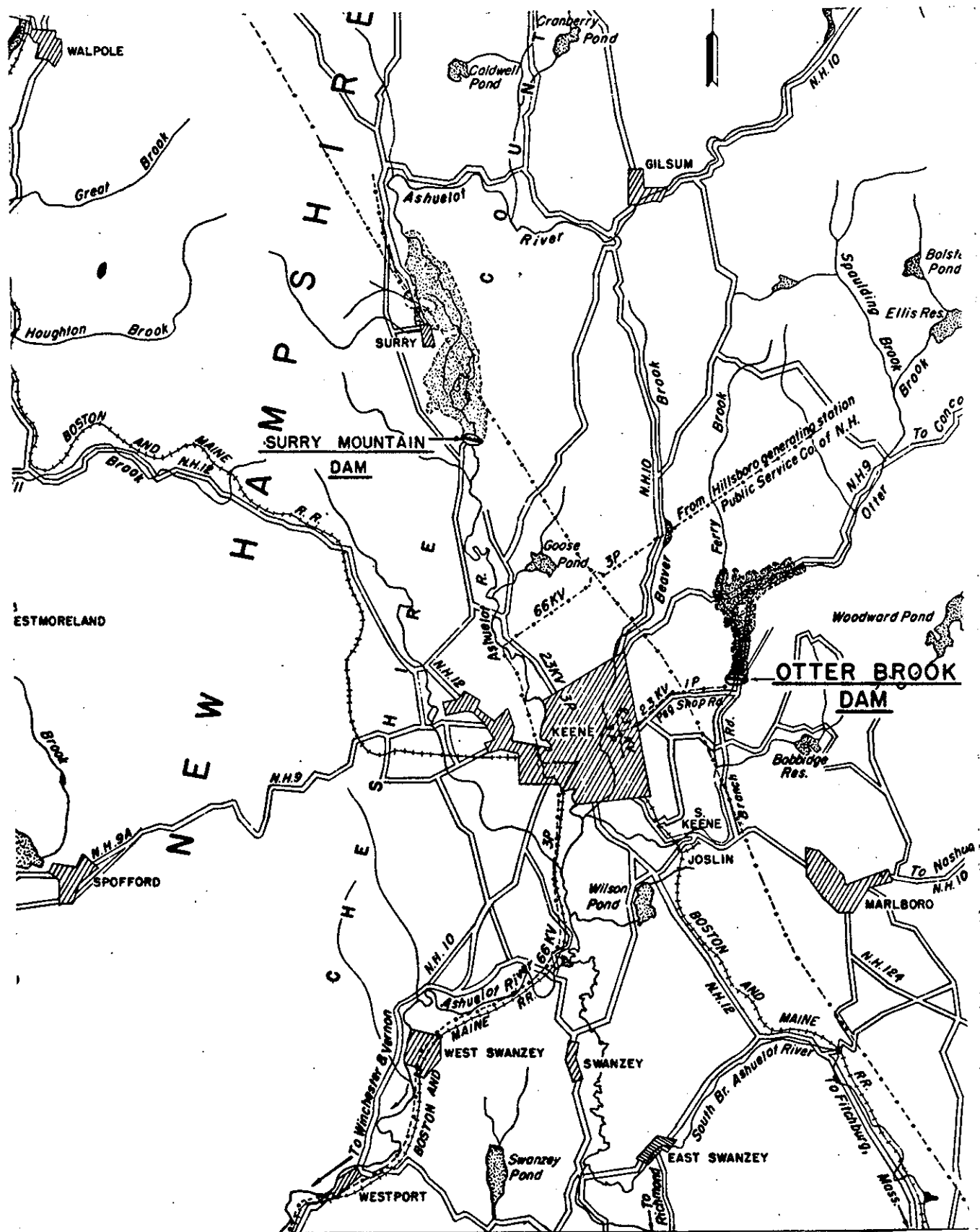
	<u>Stage</u> (Ft., NGVD)	<u>Area</u> (Acres)	<u>Capacity</u> (Acre-Feet)
Invert	683	0	0
Recreation Pool	701	70	720
Flood Control (Spillway Crest)	781	374	17,600 (net)

Embankment Features:

Type	Rolled Earth Fill
Length (feet)	1,288
Top Width (feet)	25
Top Elevation (feet, NGVD)	802
Maximum Height (feet)	133

Spillway:

Location	Right (west) abutment
Type	Ogee-shaped concrete weir
Crest Length (feet)	145
Crest Elevation (feet, NGVD)	781



# VICINITY MAP

SCALE IN MILES



FIGURE 1



### Outlet Works:

Type	Boston Horseshoe Conduit
Conduit Inside Dimensions (feet)	6.0 diameter
Length (feet)	640
Service Gate Type	Three Vertical Slide Gates
Service Gate Size (feet)	2.5 x 4.5
Capacity-Spillway Crest (cfs)	1500
Stilling Basin	none
Downstream Channel Capacity (cfs)	600

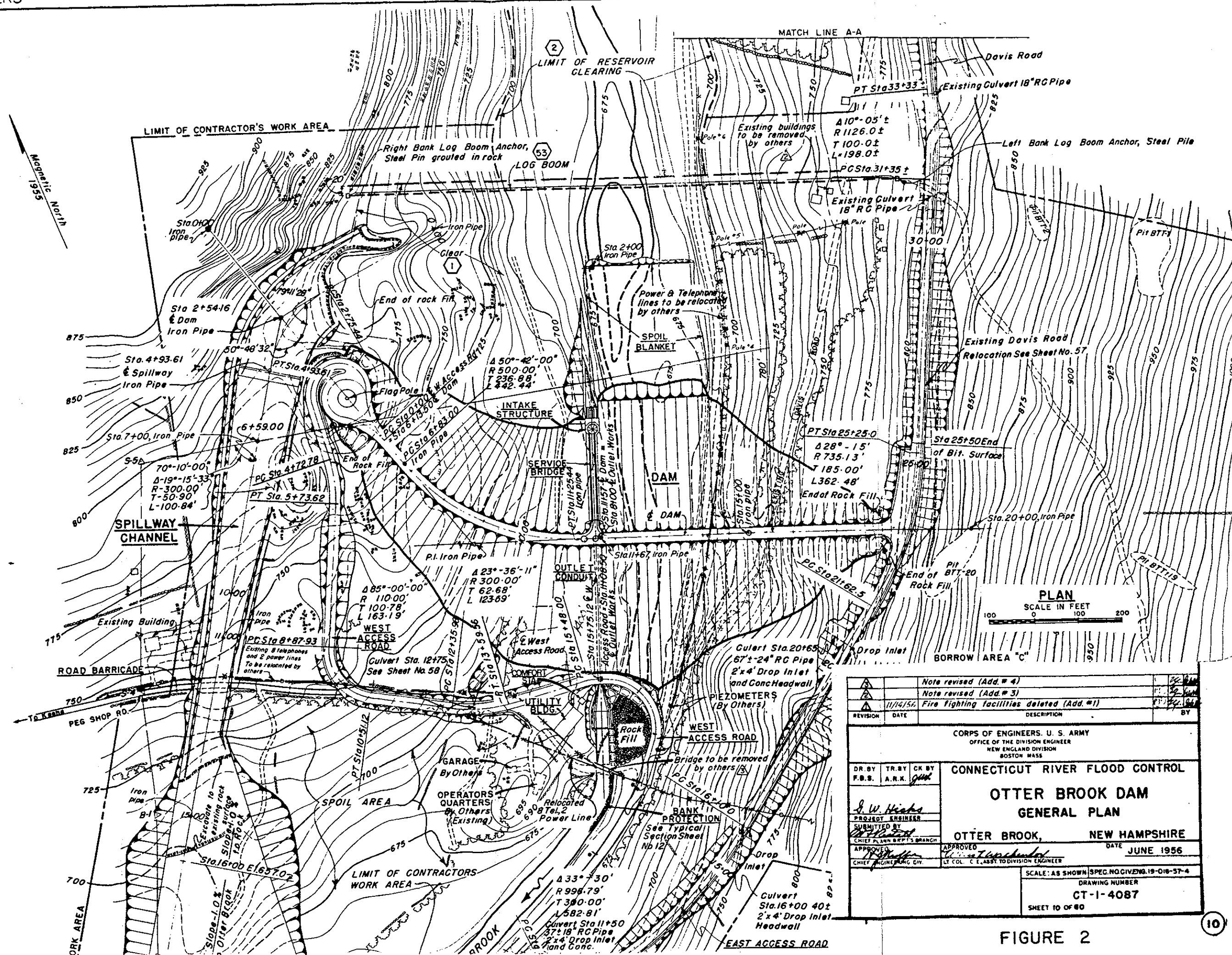
The dam embankment consists of compacted earth and rock slope protection and is 1,288 feet long with a maximum height above the streambed of 133 feet. The top of dam at elevation 802.0 feet NGVD (National Geodetic Vertical Datum) provides 17.3 feet of spillway surcharge and 3.7 feet of freeboard. The top width of 25 feet accommodates an 18-foot paved access road. The embankment slopes are 1 on 2.5.

The spillway is located in a rock cut at the west abutment. The 145-foot length of the ogee-shaped weir has a crest elevation at 781.0 feet NGVD which is 5 feet above the approach channel. The chute has a width of 142 feet at the spillway apron and transitions uniformly to a width of 60 feet in its 600-foot length. A general plan of the dam and the spillway is shown on Figure 2.

The outlet works consist of a gate chamber, control tower and operating house on the upstream side of the dam. A 6-foot diameter Boston Horseshoe discharge tunnel passes through the foundation and empties into Otter Brook at the downstream toe of the dam. The gate structure contains three 2'-6" x 4'-6" hydraulically operated vertical slide gates used for regulation purposes. The inlet elevation is 683.0 feet NGVD. The recreation pool is controlled by a weir, located immediately upstream of the center flood control gate, and having a crest elevation of 701.0 feet NGVD.

### Climate

The Otter Brook, Ashuelot River watershed is characterized by moderately warm summers, when temperatures may infrequently rise above 100° Fahrenheit and relatively cold winters, when temperatures may occasionally reach lows below minus 30 degrees, with an average annual temperature of about 46° Fahrenheit. Average annual precipitation over the watershed is about 40 inches, rather uniformly distributed throughout the year. Much of the precipitation occurring during the winter months is in the form of snow with an average annual snowfall of about 64 inches. The water content of the snow cover over the watershed normally reaches a maximum in mid-March, averaging about 4.5 inches but with some years as high as 9.5 inches water equivalent.



## Watershed

The Ashuelot River watershed is located in the southwest corner of New Hampshire in Sullivan and Cheshire Counties, with a small section in north-central Massachusetts in Franklin County. The watershed is diamond shape with a length of 42 miles and a width of 17 miles. The total watershed is 421 square miles of which 100 square miles are located above Surry Mountain Lake, a Corps reservoir located on the Ashuelot River in the town of Surry, New Hampshire and 47 square miles are located above Otter Brook Lake on Otter Brook. The Ashuelot River has a total fall of 1475 feet in its 64-mile length, most of which is concentrated near its headwaters. The terrain in the upper watershed is steep and conducive to rapid runoff above the Keene floodplain. The elevation of the watershed varies from 3,165 feet, NGVD at Monadnock Mountain in the southeastern headwaters to 227 feet, NGVD at the mouth in the southwestern portion.

The two main tributaries of the Ashuelot River are the South Branch and the Branch Rivers. The South Branch joins the Ashuelot River just above Swanzy Station, about 23.5 miles above its mouth. The Branch, formed by the confluence of Otter and Minnewawa Brooks, enters the Ashuelot River below Keene, New Hampshire, about 26.5 miles above its mouth.

Otter Brook Dam, in the headwaters of The Branch, is located on Otter Brook about 3 miles above its confluence with Minnewawa Brook. Otter Brook has a total drainage area of about 56 square miles. The brook flows in a generally southwesterly direction for about 10 miles and drops about 540 feet to Otter Brook Lake. It then flows in a southerly direction for about 3 miles to its confluence with Minnewawa Brook with a drop of about 100 feet. From Minnewawa Brook it becomes The Branch and continues in a westerly direction for an additional 3 miles and drops 80 feet to its confluence with the Ashuelot River in Keene, New Hampshire. The total drainage area of The Branch is approximately 100 square miles. The Ashuelot River watershed map, showing both Surry Mountain and Otter Brook projects is shown on Figure 3.

## Streamflow

The average annual runoff at Otter Brook Lake is approximately 23 inches or nearly 58 percent of the annual precipitation, equivalent to an average runoff rate of 1.7 cfs per square mile of drainage area.

A US Geological Survey gaging station (gage #01158600), located on Otter Brook about 400 feet downstream of Otter Brook Dam, has recorded river discharges since 1959. Table 2 lists average monthly recorded flows over the past 24 years. Since Otter Brook is operated principally for short term flood control, the monthly flows recorded at the downstream gaging station are considered representative of the natural monthly streamflows at Otter Brook Dam. Average flow at the dam was calculated to be about 79 cfs. A flow duration curve based on daily flow data for the period of record (1959 to 1982) is shown on Figure 4.

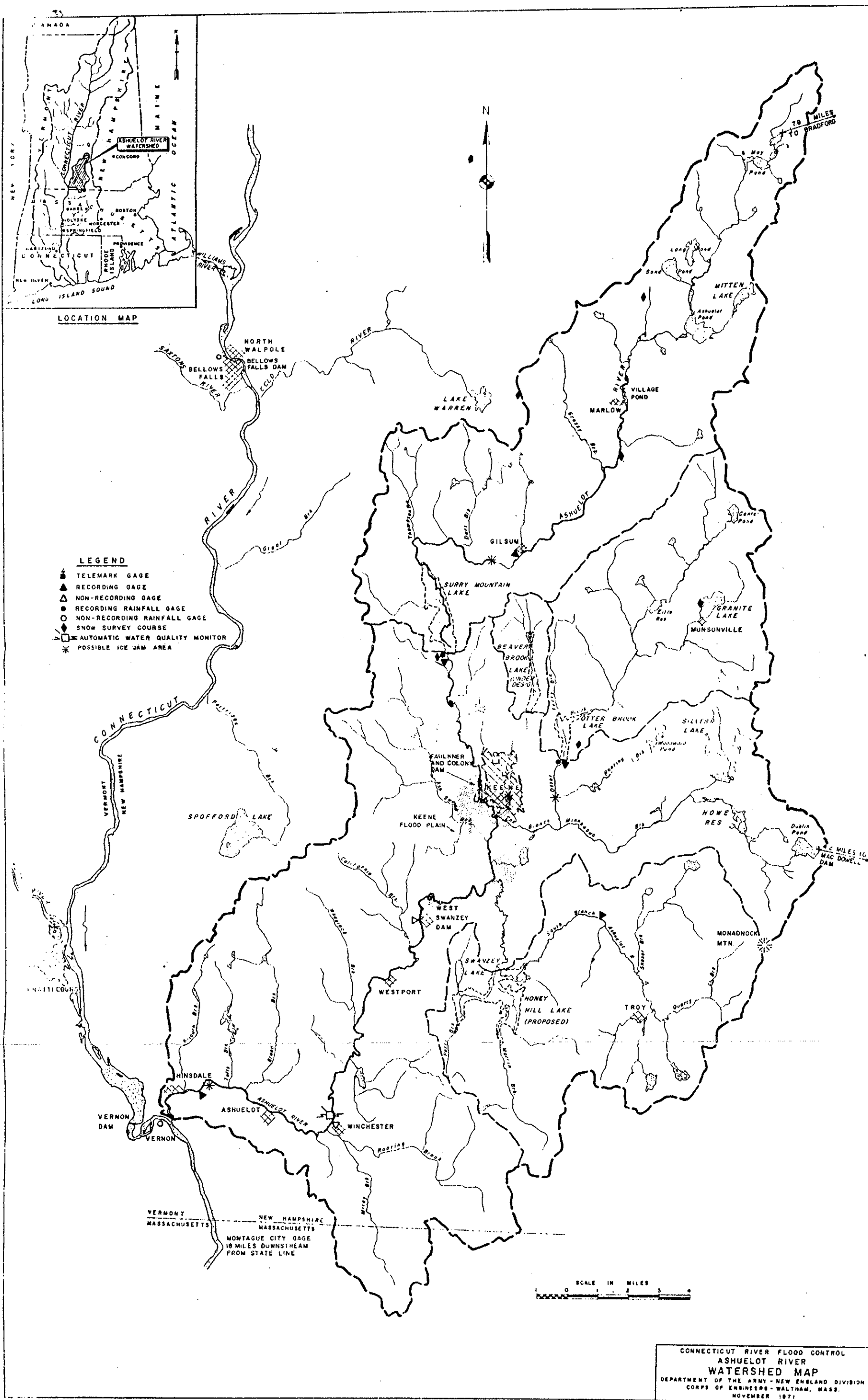


FIGURE 3

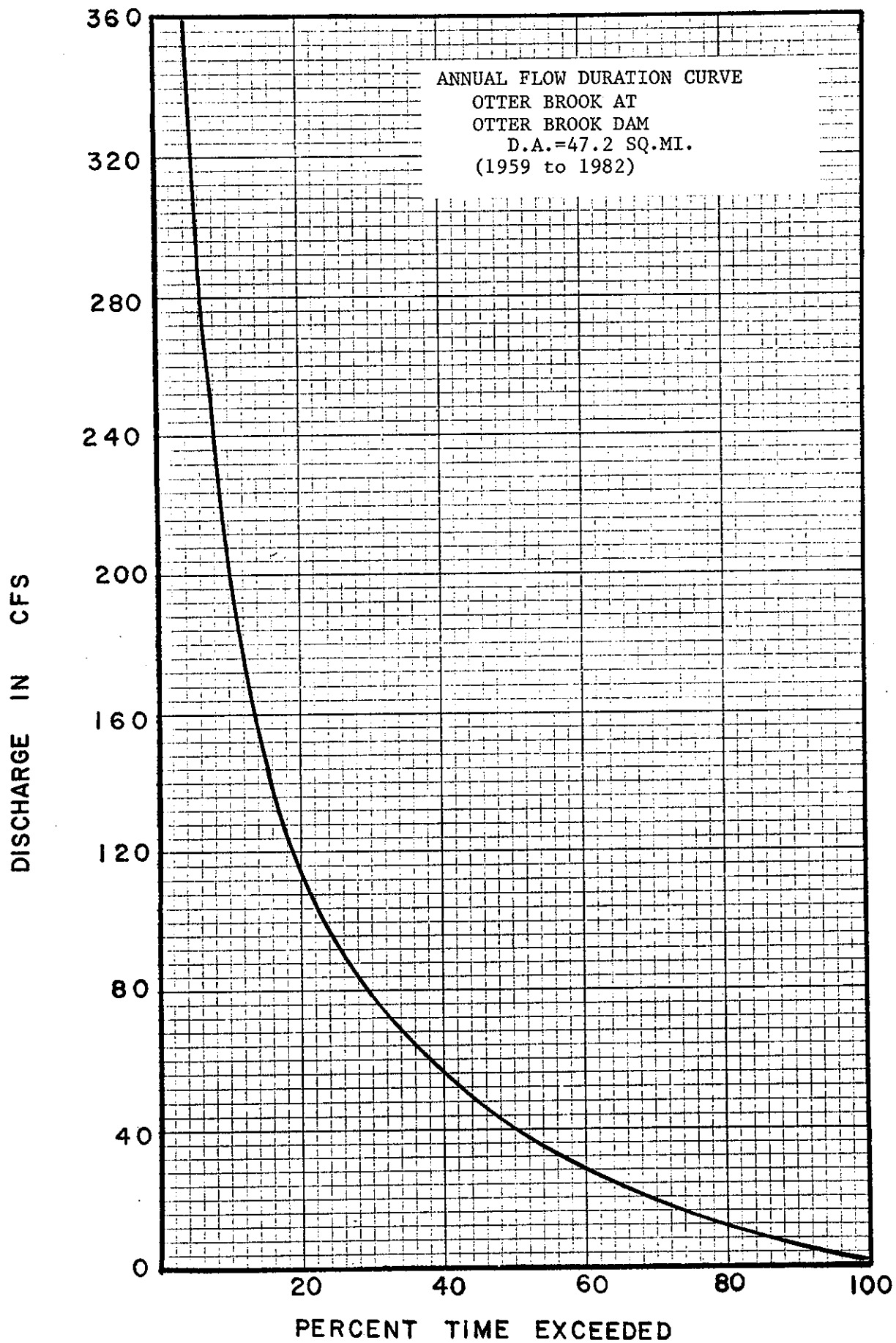


FIGURE 4

TABLE 2

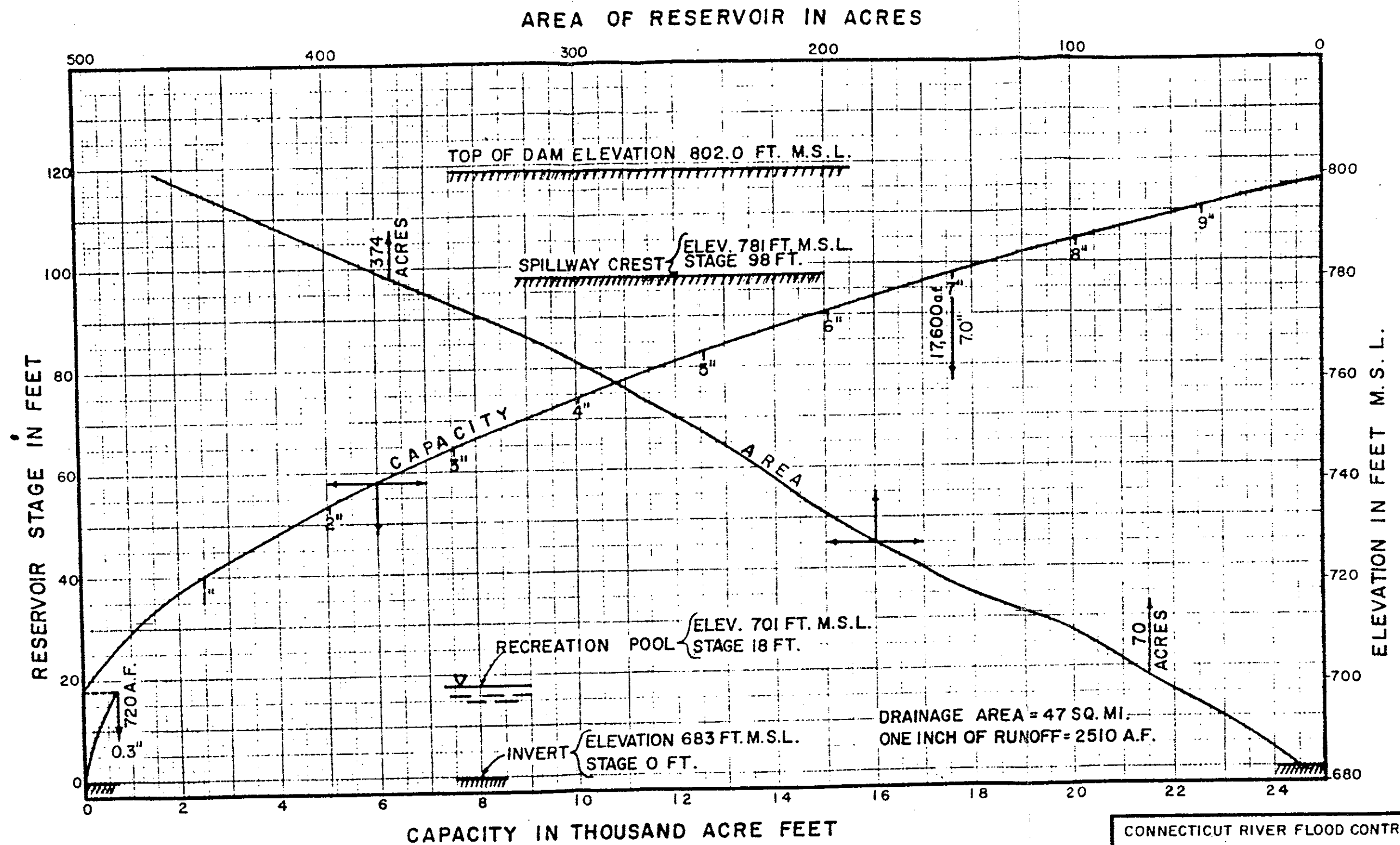
AVERAGE MONTHLY FLOWS (1959 to 1982)  
 OTTER BROOK AT OTTER BROOK DAM, KEENE, NEW HAMPSHIRE  
 (Drainage Area = 47.2 square miles)

Month	Average Flow		Percent Annual Runoff	Maximum Monthly		Minimum Monthly	
	CFS	Inches		CFS	Inches	CFS	Inches
January	64	1.57	6.9	185	4.52	9	0.22
February	63	1.39	6.1	190	4.19	15	0.33
March	131	3.21	14.1	368	8.99	30	0.73
April	262	6.20	27.3	432	10.21	130	3.07
May	119	2.92	12.9	256	6.25	40	0.98
June	50	1.19	5.2	141	3.33	4	0.10
July	25	0.62	2.7	120	2.93	3	0.07
August	19	0.47	2.1	53	1.29	2	0.05
September	22	0.53	2.3	103	2.43	1	0.02
October	46	1.13	5.0	158	3.86	1	0.02
November	68	1.62	7.2	212	5.01	3	0.07
December	76	1.87	8.2	199	4.86	13	0.32
Annual	79	22.72		126	36.24	23	6.6

#### Reservoir Storage

The Otter Brook Lake Dam is equipped with three 2.5 feet wide by 4.5 feet high outlet gates, at elevation 683.0 feet NGVD, transitioning to a single 6-foot diameter outlet conduit. There is a weir upstream of the center gate passage with a stoplog controlled crest from elevation 698.0 to 704.0 feet NGVD.

At Otter Brook Lake a small recreation pool at elevation 701.0 feet NGVD is maintained during the summer months. This 70-acre pool has a water depth of 18 feet and approximately 720 acre-feet of storage. A pool is also maintained during the winter months in order to facilitate gate operations. The winter pool at elevation 703.0 feet NGVD has a maximum water depth of 20 feet, an area of 76 acres, and utilizes a net storage, above the summer recreation pool of 150 acre-feet. During the recreation season there is a net storage of 17,600 acre-feet for flood control purposes, which is equivalent to 7.0 inches of runoff from the 47 square mile drainage area. During the late fall, winter and spring months, the net storage is reduced to 17,450 acre-feet, equivalent to 6.9 inches of runoff. The reservoir, when filled to spillway crest elevation, 781.0 feet NGVD, has a total capacity of 18,320 acre-feet, a surface area of 374 acres and a depth of 98 feet. A storage-capacity curve for Otter Brook Lake is shown on Figure 5.



CONNECTICUT RIVER FLOOD CONTROL  
 OTTER BROOK RESERVOIR  
 AREA & CAPACITY  
 CURVES

NEW ENGLAND DIVISION WALTHAM, MASS.  
 FEBRUARY 1962

FIGURE 5

## Environmental Setting

### Water Quality

The waters of Otter Brook and its tributaries upstream from Otter Brook Lake are rated Class B cold water fisheries by the New Hampshire Water Supply and Pollution Control Commission. Class B waters have high aesthetic value and are acceptable for swimming and other recreation, fish habitat, and after adequate treatment, for use as water supplies. Technical requirements for these waters include dissolved oxygen (DO) levels not less than 6 milligrams per liter (mg/l), not more than 240 total coliforms per 100 ml, turbidity not to exceed 10 JTU's, no color, odor, sludge deposits or floating solids in unreasonable quantities; and no phosphorus in such concentrations that would impair any usages assigned to this class. All of these criteria may be exceeded without violating state standards if the high levels are due to naturally occurring conditions. Class B standards contain absolute prohibitions against toxic substances in toxic concentrations or combinations, and unreasonable kinds or quantities of oil and grease.

Water quality data including physical data, dissolved oxygen, pH, primary nutrients, bacteriological, and metals data have been collected by the New England Division between 1971 and 1982 at Otter Brook Lake inflow, discharge, reservoir, and beach stations.

Data collected by NED show that Otter Brook Lake is a borderline oligotrophic-mesotrophic impoundment which exhibits weak to moderate thermal density stratification during the summer. There are no significant point source discharges upstream from Otter Brook Lake, and the waters of Otter Brook and Otter Brook Lake are of generally high quality and usually meet or exceed the standards for Class B waters. The major water quality problems are excessive sedimentation which has led to dredging the lake in 1976 and 1983, and low pH levels most likely caused by acid precipitation on poorly buffered New Hampshire soils. Other lesser problems include high color levels which reduce the water's aesthetic appeal but which are due to natural conditions; and anaerobic conditions in the bottom of the lake which cause nutrients to be released to the lake but not enough to change the lake's trophic condition. Low DO levels in the bottom of the lake do not violate State stream standards, and the weir discharge, which releases only aerated surface waters from the project, keeps downstream DO levels high.

Turbidity and fecal coliform levels are unusually low and well below the criteria for Class B waters; however, turbidity levels tend to rise during runoff events and coliform counts tend to increase during low flow conditions when flushing in the lake is reduced. Sludge deposits, oil, grease, odor, and toxic substances have not been recorded or observed at this project.



### Aquatic Ecosystem

The lower half of the permanent pool does not provide adequate fishery habitat. The upper half provides an excellent fishery habitat. Until recently, the upper half of the pool supported a viable warmwater fishery; however in the past five years a disbalance occurred in the age and size class distribution of pickerel, with larger, older fish predominating. This led to predation of the existing bass fishery, reducing their numbers to the point where action was considered necessary. Following a complete limnological survey in the summer of 1982, it was determined that the bass fishery could be reestablished, at little or no cost. In September and October, 1983, the reservoir was drawn down, and as much as possible of the existing fish population destroyed. In the summer of 1984, the New Hampshire Fish and Game Department will stock the refilled pond with 200-300 largemouth bass of breeding age. Fishing will be banned for two years to allow the new population to become established.

Otter Brook itself is stocked with trout for put and take fishing at approximately the upstream boundary of the project, servicing about 2500 feet of fishable stream. This area is heavily utilized. Ferry Brook, which feeds into the permanent pool, supports a naturally reproducing salmonid population and, in 1984, is planned for modification of the riffle-pool configuration to enhance the fishery. Currently it is not heavily utilized.

### Terrestrial Ecosystem

Approximately 73 percent of the land area of the project is forested. The forests consist of mixed hard and softwoods characteristic of the white pine-hemlock-hardwood region of southern New Hampshire. The principal softwoods include white pine and hemlock; the principal hardwoods are northern red oak, black oak and hickory, while on higher elevations yellow birch, beech, sugar maple and black cherry may be found. Along the brook, elm, black ash, red maple, alder and aspen are the dominant trees. The remainder of the project comprises developed recreational area, some fields and approximately 15-20 acres of marshland.

Fur-bearing species which are present in the Otter Brook area include woodchucks, raccoons, muskrats, beaver, mink, and fisher. Since low numbers of these species inhabit the project area, trapping activity is minimal. Deer are prevalent in the area in good numbers, and are hunted actively.

### Recreation

All recreation facilities at Otter Brook Lake are maintained and operated by the Corps of Engineers. A day-use area is located at the north end of the lake. Facilities here include a swimming beach with an adjoining parking lot for 300 vehicles, a combination rest room and change

house, a boat ramp, a picnic area with 90 tables and 45 fireplaces, two adjoining parking lots for 150 vehicles, a rest room building and a water supply system. Access to this area is off of New Hampshire Route 9. At the west end of the dam, a public overlook provides an opportunity to view the lake and the downstream river valley.

## Socioeconomic Setting

### Population

Otter Brook Dam is located on Otter Brook in the northeast area of the city of Keene, New Hampshire near the boundary of the town of Roxbury. Keene, the largest city in Cheshire County, had a 1980 population of 21,449, a 4.8 percent increase over the 1970 population. Keene is the eighth largest city in the State and accounts for one-third the population of Cheshire County. Growth in Keene has not been as rapid as growth across New Hampshire, which has experienced intense growth in the southeastern areas. Population projections provided by the New Hampshire Office of State Planning indicate modest growth of about 10 percent over the 50-year period from 1980 to 2030 to 23,547. This can be compared to projected growth in the county of 60 percent and the State of 64 percent.

The 1980 population in the town of Roxbury reached 190, an 18 percent increase over the 1970 population. The sparseness of settlement in Roxbury is similar to the density of activity in the Otter Brook Dam area. This region, however, is an attractive vacation area, and therefore experiences a noticeable influx of seasonal home residents.

### Economy

By the early 19th century, water power provided by the Ashuelot River, the Branch, Beaver Brook and Otter Brook, attracted mills engaged in finishing and weaving cloth and woodworking. Eventually, relying on the area's timber resources, the manufacture of chairs and other wood products dominated industrial activities. Late in the century, bricks manufactured in Keene were used in construction throughout New England.

Today, employment in the Keene Labor Market Area (LMA), which includes all 23 communities in Cheshire County plus Greenfield, Hancock, Peterborough, and Sharon in Hillsborough County, is concentrated in manufacturing. In 1981, employment in manufacturing accounted for 40.4 percent of the area's total employment. The manufacturing sector was followed by the services sector accounting for 23.6 percent of the area's employment opportunities and the wholesale and retail trade sector accounting for 21.4 percent. The unemployment rate in the Keene LMA in June 1983 was 4.7 percent, equal to the State's rate.

## Land Use

Keene's topography has strongly influenced land use development in the city. The valleys of the Ashuelot River and Beaver Brook have provided flat, easily, developable areas, accounting for the location of the Central Business District (CBD). Residential development has occurred in the north and the northeast parts of the city. Much of the new residential development in these areas has been low density single family homes. Major planning goals established by local planners call for the maintenance of the city's distinctive rural character by preserving at least 50 percent of the city's land as open space.

By the year 2000, land devoted to urban uses is expected to increase 55 percent and acres actively farmed are expected to decrease 48 percent. Low density residential development is expected to make the largest contribution to urban development.

The area immediately around the dam site is sparsely settled. Basically, the area is forest land. Access to the site is provided by State Route 9 connecting with local roads. Lands surrounding the dam are leased to the State and are available for recreational purposes and wildlife management.

## Historic and Archaeological Resources

While there are no recorded prehistoric archaeological sites within the Otter Brook project area, a fairly high probability exists for presence of unrecorded sites within the upper portion of the project lands. Examination of historic period maps reveals at least 7 farmstead sites and two millsites, most of which date from the 19th century or earlier. Present condition of these sites or of unrecorded historic period sites which may exist is unknown.

If the development of hydropower will alter existing pool levels or project operations, an archaeological reconnaissance survey should be investigated to determine archaeological resources present in the project area and the possible impact upon those resources.

## Reservoir Regulation

The principal purpose of the Otter Brook Dam and Lake is flood control. It provides protection for downstream communities along both Otter Brook and the Ashuelot River. It also serves as a single unit of a comprehensive system of reservoirs which operate to desynchronize flood stages on the mainstem of the Connecticut River, and to reduce flood levels in major industrial, commercial and residential centers located in Springfield, Massachusetts and Hartford, Connecticut.

A permanent recreation pool is maintained at a stage of about 18 feet by the control weir and stoplogs located immediately upstream of the center flood control gate. The two outside gates are closed and the center gate remains fully open. The gates stay in this position until the pool reaches a stage of 21 feet, at which time the Corps' Reservoir Control Center (RCC) in Waltham, Massachusetts is notified and gate changes are made upon instructions issued by the RCC.

During the freezing season the weir is submerged and the pool stage of 20 feet is maintained by operation of one outside gate. The center gates and one of the outside gates are fully closed. The pool is returned to normal levels in late March or early April upon instructions from the Reservoir Control Center.

At the time of floods all flood control gates in Otter Brook Dam are throttled closed, if necessary, to reduce flood stages on Otter Brook and the Ashuelot and Connecticut Rivers. Regulation at the dam is coordinated with other flood control reservoirs in the Connecticut River Basin to obtain optimum effectiveness of the entire system. A minimum release of about 10 cfs is maintained during periods of flood regulation in order to sustain fish life immediately downstream of the dam.

Following the recession of downstream floods on the Connecticut River, stored floodwaters are released as rapidly as possible, consistent with the amount of reservoir storage utilized, downstream flow effects, channel capacities, weather forecasts and travel times. The rate of discharge to be released from Otter Brook Reservoir depends on the relationship between Surry Mountain discharges and stages at the Island Street gate and the Keene telemark and should not exceed 600 cfs.

Evacuating storage from Otter Brook and Surry Mountain reservoirs is coordinated with releases from the other projects in the system in a manner that will allow Connecticut River flood crests to continue to recede.

Ordinarily during a major flood, the gates will not be opened to avoid spillway discharge. Surcharge storage above the elevation of the spillway crest will be utilized whenever the downstream channel capacity continues to be exceeded by the runoff from uncontrolled areas. However, if the stage in the reservoir continues to rise above the spillway crest with the possibility of endangering the structural integrity of the dam, releases would be made through the gates. Under these circumstances State and local police would be advised of the threat.

It is conceivable that extraordinary and unpredictable flood conditions may arise, such as drownings, dam or bridge failures, highway or railroad washouts, ice jams, or debris deposits. Since the prime purpose of the reservoir is to prevent or reduce damage, regulation during such unusual conditions may not follow the previously described rules but

will be governed by the urgency of the circumstances. The Reservoir Control Center will take prompt action and the gates would be operated to provide maximum protection.

It is the policy of the Corps of Engineers to cooperate with downstream water users and other interested parties or agencies. The Project Manager may be requested to deviate from normal regulations for short periods. Whenever such a request is received, the manager shall ascertain the validity of the request and obtain assurance from other downstream water users that they are agreeable to the modified operation.

#### FUTURE CONDITIONS WITHOUT THE PROJECT

No significant changes in the physical, environmental, cultural, social, or economic conditions are envisioned in the study area. No significant changes in reservoir regulation are expected. However, the projected gradual increase in population could result in subtle changes to the environment and water quality of the river.

#### PROBLEM IDENTIFICATION AND OPPORTUNITIES

The increasing scarcity of inexpensive energy has forced the United States to propose a national energy policy. This proposed policy has encouraged the nation to broaden its mix of energy sources. The New England region is heavily dependent on oil as a fuel source for electrical energy generation. The New England Power Pool (NEPOOL) has indicated that approximately 60 percent of the existing capacity of the region is contained in oil-fired generation units, which would be affected by fuel shortages that could occur in the immediate future. The instability of oil supplies coupled with fluctuating associated prices has encouraged the expanded use of coal and alternative energy sources. Small hydropower installations are one of these alternative energy sources that can reduce the region's dependence on oil.

Development of the hydropower potential at Otter Brook Dam provides an opportunity to develop a safe, dependable, environmentally sound, relatively inexpensive source of electricity. The savings in cost of power production would be realized by hundreds of households. The conservation of fossil fuels can be measured in thousand of barrels of oil annually. This project is an opportunity to contribute to solving the continuing problem of the United States' increasing dependence on oil-generated electricity.

#### PLANNING GUIDANCE

General planning guidance for this investigation are contained in Public Law 91-190, National Environmental Policy Act; Public Law 91-611, River and Harbor and Flood Control Act of 1970; Public Law 92-500, Federal Water Pollution Control Act Amendments of 1972; Public Law 93-251, and Public Law 94-587, Water Resources Development Acts of 1974 and 1976,

respectively; Public Law 95-217, Clean Water Act; and the "Principals and Guidelines for Planning Water and Related Land Resources" guidance as amended by the President's Council on Natural Resources and Environment.

#### PLANNING CONSTRAINTS

The primary purpose of this project is flood control. Any hydropower addition to this project must not interfere significantly with flood control purposes.

In the design of any hydroelectric generating facilities, measures must be taken, to the extent possible, to minimize environmental and social disruptions and still optimize the power potential of the site.

Hydrologic studies associated with assumptions regarding possible significant infringement on existing flood control storage and impacts on reservoir regulation activities as well as detailed design and cost estimates are beyond the scope of this reconnaissance investigation. Future studies will include detailed hydrologic, water quality and regulation considerations to determine whether any infringement on flood control storage would have a significant adverse impact on the Connecticut River Basin flood control protection. For this report, assumptions have been made on the premise that the Corps would plan, develop, construct and operate any hydropower additions to the project.

#### FORMULATION OF PLANS

The purpose of this investigation is to determine the feasibility of adding hydroelectric generating facilities to the Otter Brook project. In view of the limited scope of this reconnaissance effort due to funding constraints, it was decided that only run-of-river hydropower alternatives would be considered at this time. No attempt was made to investigate the development of the nearby Surry Mountain flood control project for hydroelectric generation in conjunction with development at Otter Brook Dam. The different schemes investigated are intended to displace a combined cycle oil-fired thermal facility. The schemes are designed to be operated as run-of-river projects thereby minimizing fluctuations of the reservoir level during hydropower operations.

#### HYDROPOWER ESTIMATES

The hydropower potential of a volume of water is a function of its weight and the vertical distance it can be lowered. The function of a water power facility is to transform this gravitational potential energy into mechanical energy, by turning a turbine, thence into electrical

energy via a generator. The rate of power generation, normally measured in kilowatts, is determined by the formula:

$$P = \frac{EHQ}{11.8}$$

where

P = Power or capacity in kilowatts  
E = Combined turbine and generator efficiencies  
Q = Rate of discharge in cubic feet per second  
H = Net hydraulic head in feet

With today's highly efficient turbines and generators, an average combined efficiency of 80 percent can be reasonably assumed for a typical range of operating head and discharge conditions. The potential amount of energy generation over a period of time is normally measured in kilowatt-hours and is equal to the average capacity times the duration of generation.

The potential amount of water power of any stream is a function of: (1) the average streamflow, and (2) the average annual hydraulic head. Both the rate of discharge and the head are quantities which may fluctuate; therefore, it is the magnitude of these two quantities and their variability that determines the potential energy of a site and its dependability.

There are both flow and head limitations on the operating capability of hydraulic turbines. The upper and lower turbine flow limits are typically expressed as a function of the design discharge, i.e., the flow that will produce the maximum turbine output at the design head. The allowable operating range of a turbine is determined by the type of turbine and its characteristics. The operating limits of the selected turbine are plotted on the flow duration curve. The area under the curve inclosed by these limits establishes the theoretical average flow available to the turbine 100 percent of the time. This flow is converted into an average power output from the previously described power equation multiplied by 8,760 hours in a year, giving the average annual energy, in kilowatt-hours, which could be generated by a plant of the assumed capacity.

There are two basic classes of hydraulic turbines to select from for a given situation, namely impulse and reaction turbines. Impulse turbines are driven by kinetic energy produced by jets of water impinging on buckets attached to the rim of the runner. Reaction turbines are driven by the combined pressure and velocity of water passing through blades attached to the runner. In general, an impulse turbine will not be competitive in cost with a reaction turbine where the available head of water is less than 1,000 feet.

Reaction turbines are classified as either Francis (mixed flow) or Propeller (axial flow). Both Propeller and Francis turbines may be mounted either horizontally or vertically. Additionally, Propeller turbines may be slant mounted. A Francis turbine is one having a runner with fixed buckets (vanes), usually nine or more, to which the water enters the turbine in a radial direction, with respect to the shaft, and is discharged in an axial direction. A Francis turbine may be operated over a range of flows from approximately 40 to 105 percent of rated discharge. The approximate head range for operation is from 60 to 125 percent of design head. A propeller turbine is one having a runner with four, five, or six blades in which the water passes through the turbine in an axial direction with respect to the shaft. Propeller turbines may be operated at power outputs with flows from 40 to 105 percent of the rated flow. Head ranges for satisfactory operation is from 60 to 140 percent of design head.

Generators are either synchronous or induction types. The synchronous unit is equipped for self excitation and synchronization before going onto the power grid, whereas the induction generators relies on power from an outside source for excitation. Induction generators are somewhat cheaper and more applicable to small power installations but the number of small units attached to the power supply system must be controlled because too many units could cause a draining effect from the grid for excitation. For this study it was assumed that generators would have rated capacities equal to or greater than the rated turbine capacities and also be capable of operating at a 15 percent overload.

Consideration was given to locating the powerhouse further downstream than the toe of the existing dam in order to increase the available hydraulic head for power generation. However, construction of a longer penstock to a remote powerhouse site would not be an incrementally economic solution due to the relatively gentle slope of Otter Brook downstream of the dam. It was also recognized that water hammer in a long penstock could become a problem that would require the installation of pressure relief valves or a surge tank to avoid damage to the turbines and generating equipment.

#### DESCRIPTION OF HYDROPOWER ALTERNATIVES

Three alternatives were formulated for evaluation to determine the feasibility of adding hydroelectric generation facilities at Otter Brook Lake. All three alternatives were designed as run-of-river operations and would require increasing the permanent pool to 715 feet, NGVD, an increase of 12 feet over the existing winter pool. Two of the alternatives are conventional hydropower developments which utilize the flood control outlet as a penstock to convey flows to a powerhouse located downstream of the toe of the dam. The third alternative would utilize submersible turbine-generator equipment installed in a weir upstream of the flood control gates. No generation would occur during the summer months and the pool would be returned to 701 feet NGVD for that season.

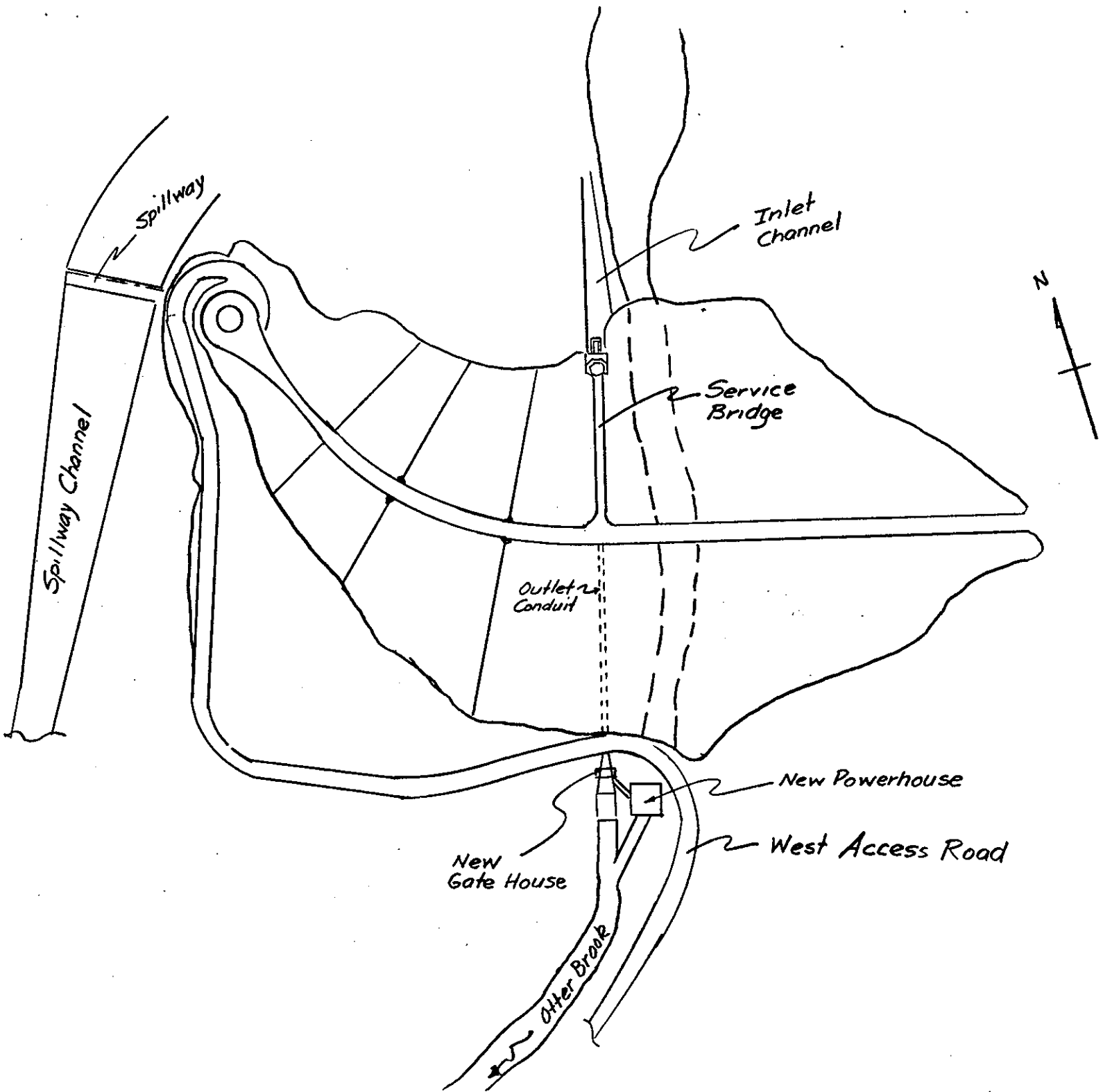


Alternative 1 would utilize the flood control outlet to divert flows to a powerhouse located approximately 330 feet downstream of the dam, thereby creating a new hydraulic head of 42.5 feet. The outlet tunnel will require steel lining to withstand pressures from power operations. The outlet tunnel will be extended 50 feet downstream and a new gate structure would be constructed to allow the outlet to be used for either flood control discharges or hydropower generation. A branch penstock approximately 200 feet in length would convey water from the new gate structure to the powerhouse.

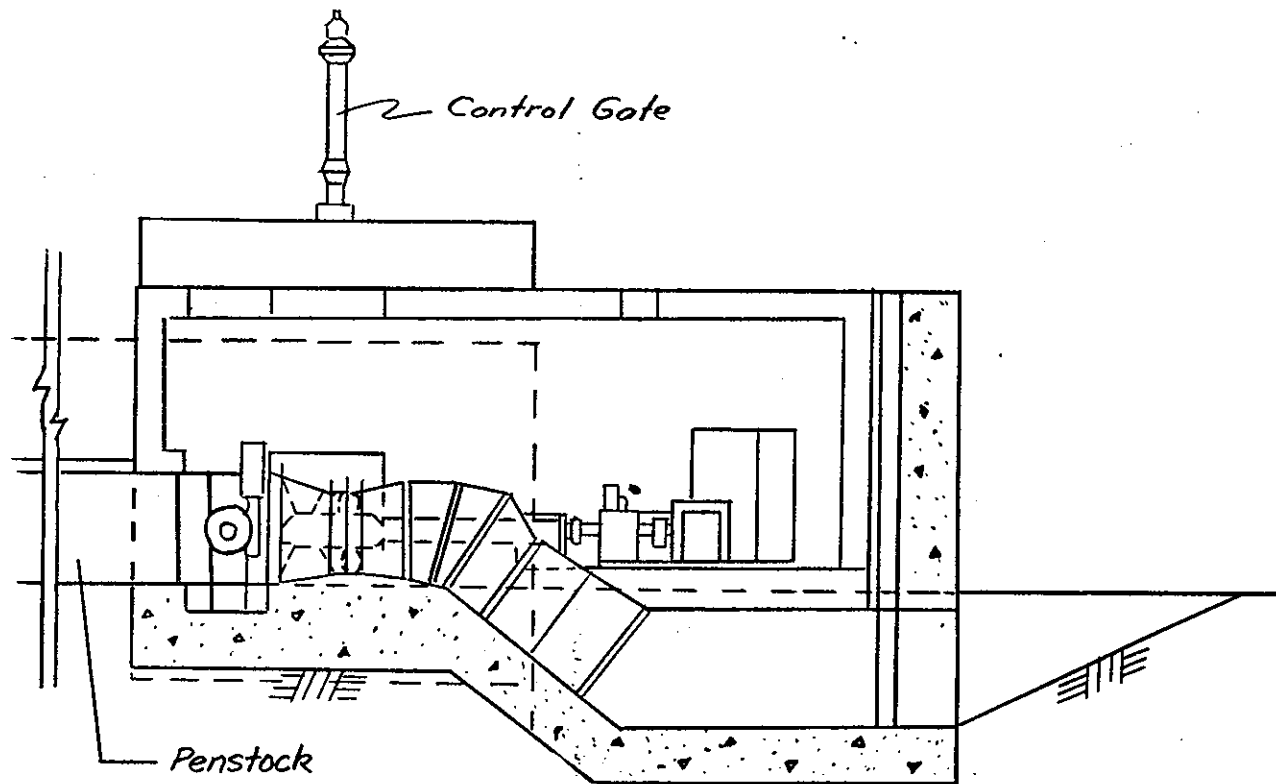
The powerhouse would contain two equal sized standard tube turbines with synchronous generators with installed capacities of 150 kw. Utilizing two units gives operational flexibility and allows generation whenever flows range between 21 cfs and 110 cfs. Whenever flows are below 21 cfs generation would cease. This alternative would generate an average of 1,257,000 kilowatt-hours (kwh) annually. Pertinent data on Alternative 1 is presented in Table 3 and typical sketches of the alternative are illustrated on Figures 6 and 7.

Alternative 2 would also utilize the flood control outlet to divert flows to the proposed powerhouse located 300 feet downstream of the dam. Alternative 2 is identical to Alternative 1 except for the size turbines and generators to be installed in the proposed powerhouse. The powerhouse in Alternative 2 would contain two unequal sized standard tube turbines with synchronous generators with installed capacities of 350 kw and 150 kw, respectively. This alternative would be capable of generating electrical energy whenever flows are between 21 cfs and 182 cfs and could produce an average of 1,541,000 kwh annually. Pertinent data on this alternative is presented in Table 3 and typical sketches of the alternative are also illustrated on Figures 6 and 7.

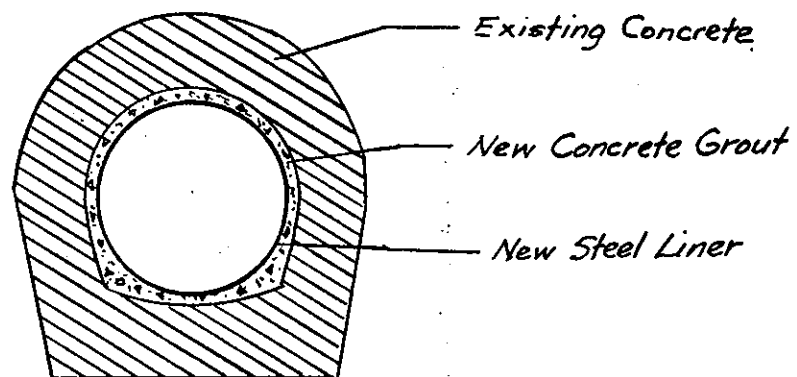
Alternative 3 would require the replacement of the existing weir upstream of the center flood control gate with a new 35 foot high weir into which a mini-submersible turbine/generator unit would be installed. This unit is equipped with an inductive generator having an installed capacity of 117 kw. Generation would occur whenever flows are between 38 cfs and 54 cfs. This alternative is capable of generating an average of 499,500 kwh of energy annually. Since the entire unit is submersible there is no need for the construction of a separate powerhouse. The controls to the unit can be installed in the flood control tower directly above the weir. No modifications to the outlet tunnel are required in Alternative 3 since the tunnel is not pressurized during hydropower operations. Pertinent data on this alternative is presented in Table 3 and typical sketches are illustrated in Figures 8 and 9.



Otter Brook Lake  
Alternatives 1 & 2  
Plan View

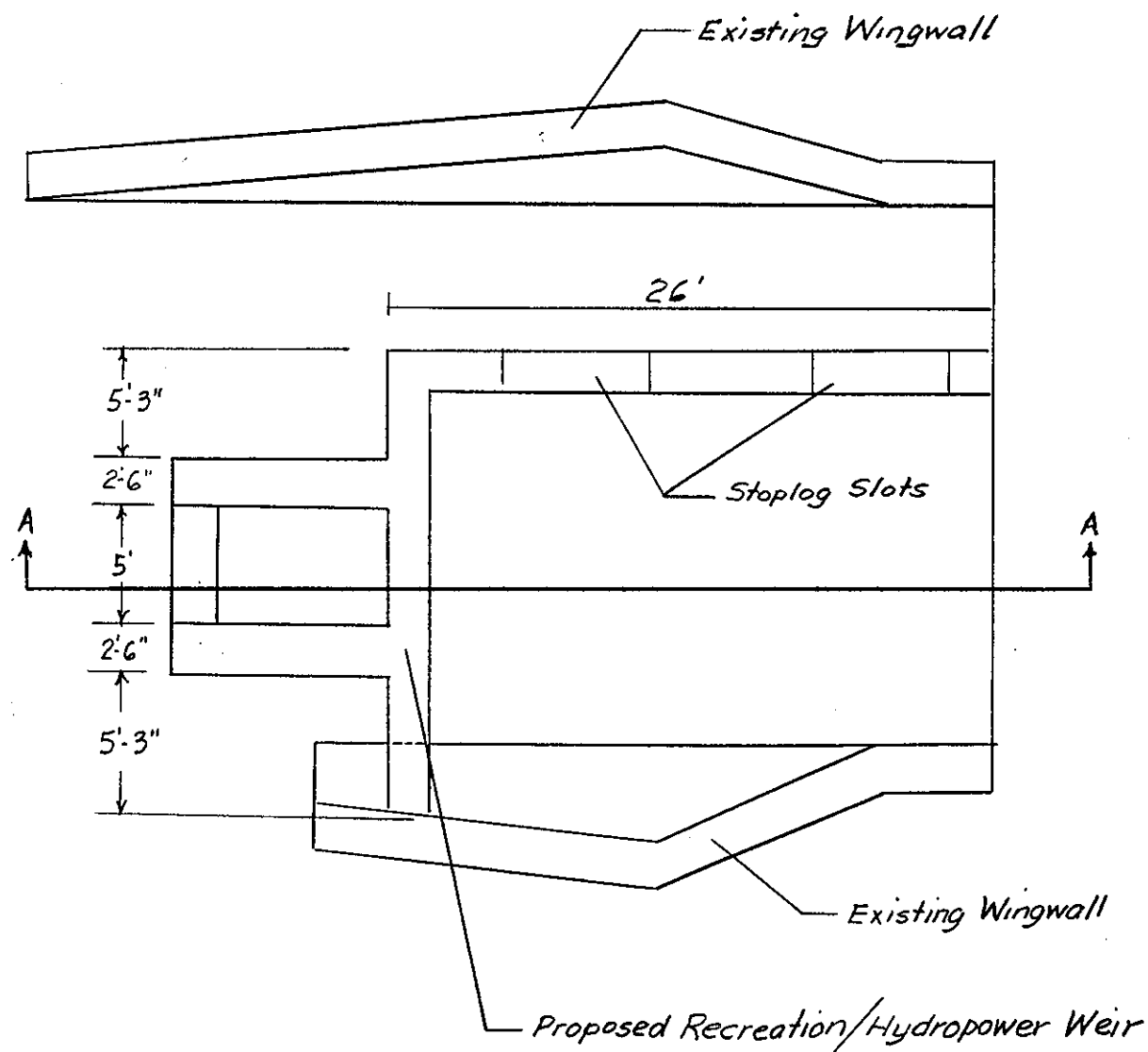


SECTION ALONG  $\phi$  OF TURBINE



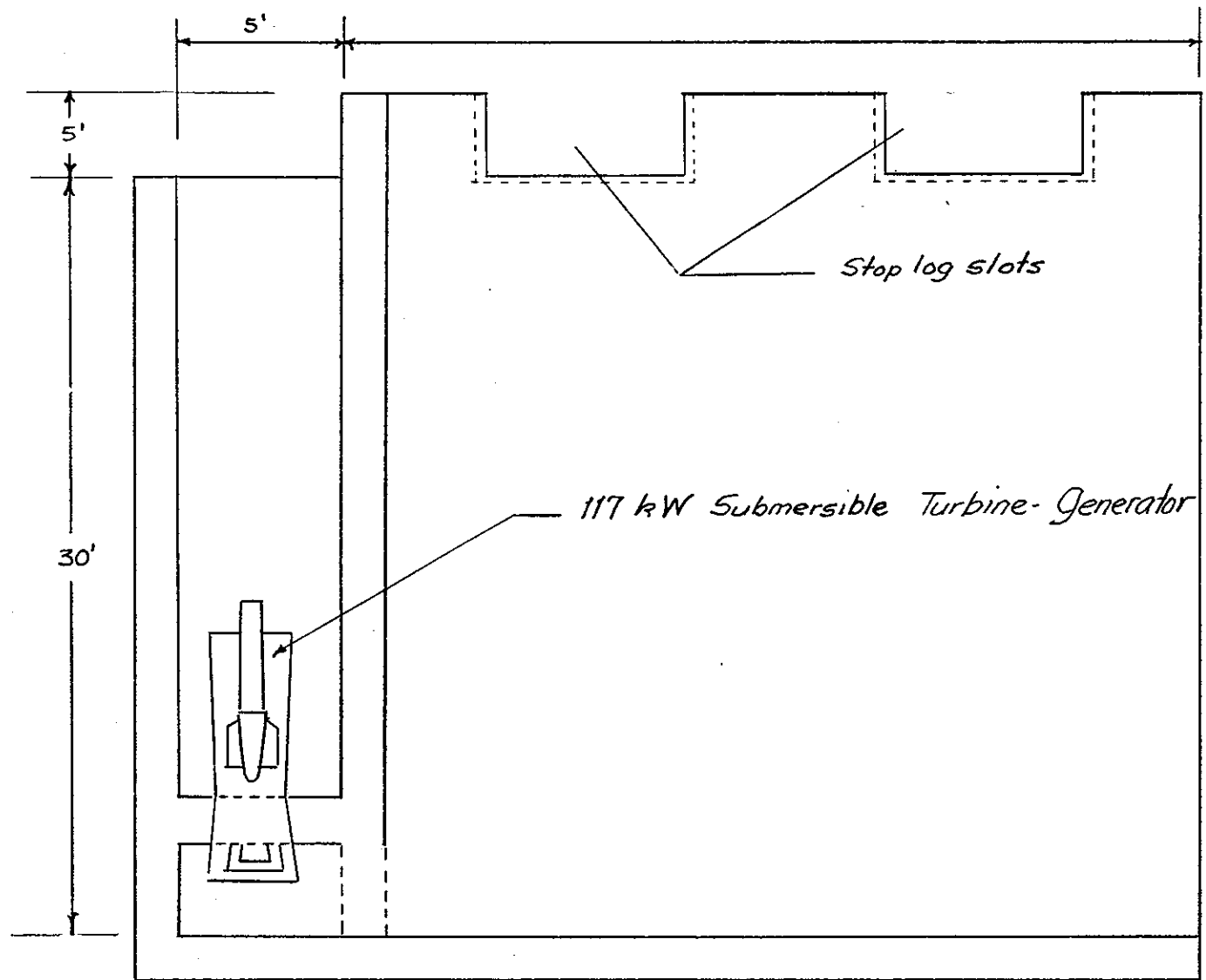
Section Existing Outlet  
not to scale

Otter Brook Lake  
Alternatives 1 & 2  
Section View



Otter Brook Lake  
Alternative 3  
Plan View  
not to scale

Figure 8



Offer Brook Lake  
Alternative 3  
Section View

Figure 9

TABLE 3

## PERTINENT DATA - HYDROPOWER DEVELOPMENT

	<u>Alternative 1</u>	<u>Alternative 2</u>	<u>Alternative 3</u>
Turbine Type	tube	tube	submersible
Number of Units	2	2	1
Generator Type	synchronous	synchronous	inductive
Generator Capacity (kw)	(2) 150	350 and 150	117
Net Hydraulic Head (feet)	42.5	42.5	30
Flow Range (cfs)	21-110	21-182	38-54
Average Annual Energy (kwh)	1,257,000	1,541,000	499,500
Plant Factor	48	35	49

## COST ESTIMATES

Cost estimates have been prepared either by using cost curves and tables taken from the Corps publication entitled "Feasibility Studies for Small Scale Hydropower Additions" or by preparing site specific estimates using standard engineering practices for items not covered by the guide manual. Estimates for the project first costs for Alternatives 1 and 2 are presented in Table 4. An estimate of the project first cost of Alternative 3 is presented in Table 5. No new roads or relocations other than a small paved service area are required. All costs for construction are based on October 1983 price levels. The project life is assumed to be 100 years. The interest rate utilized in determining the annual costs, presented in Table 6, was 8-1/8%.

TABLE 4

## PROJECT FIRST COSTS - ALTERNATIVES 1 AND 2

<u>Item</u>	<u>Alternative 1</u>	<u>Alternative 2</u>
Parking & Miscellaneous Site Features	\$ 50,000	\$ 50,000
Environmental Controls	10,000	10,000
Turbines/Generators	325,000	690,000
Station Electric Equipment	117,000	146,000
Switchyard Equipment	58,000	73,000
Transmission Line	15,000	15,000
Miscellaneous Powerplant Equipment	36,000	51,000
Grading, Drainage & Erosion Controls	10,000	10,000
Penstock	53,000	53,000
Bifurcations	22,000	22,000
Powerhouse	200,000	250,000
Gate & Outlet Extension	150,000	150,000
Tunnel Lining	<u>80,000</u>	<u>80,000</u>

Subtotal	\$1,126,000	\$1,600,000
Contingencies	225,000	320,000
Construction Cost	<u>\$1,351,000</u>	<u>\$1,920,000</u>
Engineering & Design	135,000	192,000
Supervision & Administration	<u>94,000</u>	<u>138,000</u>
Total Project First Cost	\$1,580,000	\$2,250,000

TABLE 5

PROJECT FIRST COST -- ALTERNATIVE 3

<u>Item</u>	<u>Cost</u>
Concrete Excavation	\$ 9,200
Reinforced Concrete	79,500
Turbine/Generator	76,000
Upstream Gate	20,000
Stop Logs	1,000
Trashrack	5,000
Electrical Equipment	25,000
Transmission	15,000
Site Preparation	5,000
Control of Water	<u>25,000</u>
Subtotal	\$260,700
Contingencies	52,300
Construction Cost	<u>\$313,000</u>
Engineering & Design	33,000
Supervision & Administration	<u>22,000</u>
Total Project First Cost	\$368,000

TABLE 6

ANNUAL COST OF ALTERNATIVES

<u>Item</u>	<u>Alternative 1</u>	<u>Alternative 2</u>	<u>Alternative 3</u>
Project First Cost	\$1,580,000	\$2,250,000	\$368,000
Interest During Construction	<u>90,000</u>	<u>140,000</u>	<u>22,000</u>
Total Investment Cost	\$1,670,000	\$2,390,000	\$390,000
Interest & Amortization	135,700	194,300	31,700
Operation & Maintenance	24,300	39,700	2,300
Replacement	<u>3,000</u>	<u>5,000</u>	<u>2,000</u>
TOTAL ANNUAL COST	\$163,000	\$239,000	\$36,000

## ALTERNATIVE EVALUATION

### ECONOMIC ANALYSIS

The purpose of this section is to estimate the economic benefits and determine the economic feasibility of certain hydropower additions to the existing flood control facility at Otter Brook Lake.

The conceptual basis for evaluating the benefit from energy produced by hydropower plants is society's willingness to pay for these outputs. It is a universally accepted economic concept that society is best served in making resource allocation decisions by pricing output equal to marginal costs. However, historically there have been difficulties in applying this concept to the electric utility sector due to differing interpretations and various estimation methods. Recognizing the interest in the development of small hydropower throughout the nation and realizing that a value must be assigned to its output, Congress passed "The Public Utility Regulatory Policies Act of 1978 (PURPA)", effective March 20, 1980. The rules of this Act require utilities to purchase energy and capacity from small-scale hydro plants (under 80 megawatts) using the concept of "marginal" or "avoided" or "incremental" costs. The Federal Energy Regulatory Commission (FERC) was requested to place a value on the power to be produced by the hydropower developments under consideration at Otter Brook. FERC accomplished this task using the following method: (1) estimate the resource cost of the most likely thermal alternative to be implemented in the absence of hydropower development, (2) perform a "life-cycle cost" analysis for the most likely alternative in which projected fuel cost increases are factored into the total resource cost and (3) measure the "displaced" or "avoided" energy cost that the hydropower addition will accomplish in the existing electrical generation system.

#### Most Likely Alternative

FERC has assumed that the most likely alternative to a hydropower addition at Otter Brook would be a conventional coal-fired steam plant. Oil-fired combined cycle plants are no longer considered a viable alternative due to the high cost of oil, the uncertainty of the world oil situation, national efforts to reduce our dependence on foreign oil supplies and the absence of this type of generation from utility expansion plans. The resource cost of the coal-fired plant is composed of two components, the capacity cost and the energy cost. The measure of the value of the hydropower project's generating capacity is the total of the coal plant's amortized investment cost, transmission cost, interim replacement costs and fixed operating and maintenance costs. The three alternatives at Otter Brook have capacity factors of 48 percent, 35 percent and 49 percent, respectively, which places their annual generation in the base band on the market load curve. FERC criteria for the ranges of generation are: peaking power - annual capacity factors up to and including 15 percent which corresponds to 1,300 hours of annual operation;



intermediate power-annual capacity factors over 15 percent and up to 30 percent which corresponds to 2600 hours of annual operation and base load-greater than 30 percent capacity factor. Power values estimated under this methodology are found in Table 7.

TABLE 7

POWER VALUES - MOST LIKELY ALTERNATIVE

<u>Power Value</u>	<u>Alternative 1</u>		<u>Alternative 2</u>		<u>Alternative 3</u>	
	<u>At-Market</u>	<u>At-Site</u>	<u>At-Market</u>	<u>At-Site</u>	<u>At-Market</u>	<u>At Site</u>
Capacity (\$/kw/yr)	226	145	226	180	226	145
Energy (Mills/kwh)	21	20	13	12	21	20

Life Cycle Cost

The measure of the benefit to the hydropower plant in terms of the energy value is predominantly affected by the cost of fuel consumed by the thermal alternative. The determination of fuel costs is therefore critical in the evaluation of hydropower as they control a significant portion of the benefits. The Principles and Guidelines specifically require evaluation of real escalation in fuel prices when the alternative to hydropower is a thermal plant. The cost of fuel for the most likely alternative to Otter Brook, the coal plant, was estimated to be \$2.10 per million Btu based on an October 1983 telephone survey of the electric utilities in New England. Fuel price projections used in the life cycle cost analysis were prepared by the Energy Information Administration (EIA) in 1983. The regional New England projections used are derived from the Middle World Price (MIDOP) forecast scenario in the EIA publication, "1982 Annual Energy Outlook", released in April 1983. Using these projections fuel cost escalations were derived for the period 1983-2010. After 2010, fuel prices were considered to increase along with the general rate of inflation; i.e., no increase using constant dollars. All energy costs were discounted to 1989, Otter Brook's hydropower project's anticipated on-line date, to obtain their present worth then converted to a levelized annual value through application of a capital recovery factor. The power values based on life cycle cost analysis are presented in Table 8.

TABLE 8

POWER VALUES - LIFE CYCLE COST ANALYSIS FOR MOST LIKELY ALTERNATIVE

<u>Power Value</u>	<u>Alternative 1</u>		<u>Alternative 2</u>		<u>Alternative 3</u>	
	<u>At-Market</u>	<u>At-Site</u>	<u>At-Market</u>	<u>At-Site</u>	<u>At-Market</u>	<u>At Site</u>
Energy (Mills/kwh)	24	23	15	14	24	23

## Displaced Energy Analysis

This method estimates the cost of the energy that the hydropower addition at Otter Brook will displace from the existing generation system. It is especially applicable in cases where the hydropower addition is small in scale, with no dependable capacity, and it is evident that a thermal alternative will not be built in the absence of construction of the hydroplant. The methodology for the displaced energy cost analysis is based on the Water Resources Council task force report entitled, "Implementing Procedures for Evaluating Hydropower Benefits", dated December 1981. In simple terms the benefit under this method is the difference in system costs incurred by a utility (system) to meet a specific demand without the Otter Brook hydropower addition compared to the cost the utility would incur with the Otter Brook hydropower plant meeting part of the demand and the balance supplied by other facilities. To accomplish this, a life cycle cost analysis was performed on the energy displaced by Otter Brook year-by-year beginning with 1989, the project on-line date. In this analysis, the projected real price increases of fuel oil were utilized since oil-fired generation would be displaced by the hydropower plant. The annual load duration curves for New England were synthesized from data contained in the Northeast Power Coordinating Council (NPCC), Long Range Coordinated Bulk Power Supply Programs report and load duration curves provided by the New England Power Exchange (NEPEX). The type of generation displaced was then determined from the capacity band stackings on the annual load duration curve. The projected capacity mix is available from the NPCC reports through the year 2002. After 2002 and through 2089 it was assumed that there would be no further changes in the types of generation displaced. The displaced energy method appears to be the most appropriate for the evaluation of hydropower additions at Otter Brook due to factors of small installed capacity and lack of dependable capacity. The power values based on the displaced energy analysis are illustrated in Table 9.

TABLE 9

### POWER VALUES - DISPLACED ENERGY ANALYSIS

<u>Power Value</u>	<u>Alternative 1</u>		<u>Alternative 2</u>		<u>Alternative 3</u>	
	<u>At-Market</u>	<u>At-Site</u>	<u>At-Market</u>	<u>At-Site</u>	<u>At-Market</u>	<u>At Site</u>
Energy (Mills/kwh)	81	62	88	72	81	62

### Determination of Economic Feasibility

The economic feasibility or justification of the proposed hydropower alternatives at Otter Brook Lake is determined by comparing the annual benefits with the annual costs. The resulting benefit/cost ratio must be 1.0 or greater for an alternative to be considered economically justified

and eligible for Federal participation. The annual benefits for each alternative are derived by multiplying the annual energy output by the unit energy value, provided by FERC, which represents the value of displaced energy cost in the New England Power Pool. A summary of the economic analysis is illustrated in Table 10.

TABLE 10

SUMMARY OF ECONOMIC ANALYSIS

	<u>Alternative 1</u>	<u>Alternative 2</u>	<u>Alternative 3</u>
Installed Capacity (kW)	300	500	117
Capacity Factor	48	35	49
Average Annual Energy (kwh)	1,257,000	1,541,000	499,500
Energy Value (mills/kwh)	81	88	81
Annual Benefits	\$101,800	\$135,600	40,500
Annual Costs	\$163,000	\$239,000	36,000
Benefit/Cost Ratio	0.62	0.57	1.13
Net Benefits	(\$61,200)	(\$103,400)	\$4,500

The energy values shown in Table 10 were developed by FERC and transmitted by letter, dated 30 January 1984 for use in this study.

The results of the economic analysis indicate that Alternatives 1 and 2 with benefit/cost ratios of 0.62 and 0.57, respectively, are not economically justified. Alternative 3, however, is considered economically justified since its benefit/cost ratio exceeds unity.

ENVIRONMENTAL ASSESSMENT OF HYDROPOWER DEVELOPMENT

Topography, Geology, and Climatology

The addition of hydroelectric facilities at Otter Brook Lake is not expected to have any significant impacts on the topography, geology, or climatology of the area. Although construction of the penstocks and powerhouse downstream of the dam in Alternatives 1 and 2 would require removal of surface materials immediately downstream of the dam, this activity would have little affect on the natural topography and geology of the site since both were altered during dam construction. A fluctuation of the pool during hydropower operations may result in some minor erosion and sloughing of the steeper reservoir slopes. This does not present a hazard and the area should stabilize itself within the first few years of operation.

Historical and Archaeological Resources

The development of run-of-river hydropower at Otter Brook Lake would not affect any properties of architectural or historical significance that may be eligible for inclusion in the National Register, nor would this

type of development have any affect on archaeological resources due to the previously disturbed ground when the existing project was constructed. However, during advance design stages reconnaissance surveys would be conducted to determine more closely the effects of hydropower development.

#### Recreational Resources

The raising of the pool 12-feet for hydropower operations will inundate the swimming beach at the recreational area of the reservoir. The pool will be returned to the normal summer level so as not to interfere with the recreation season. The beach is currently restored annually to correct damage caused by storage of spring runoff.

#### Water Quality

The water quality changes caused by hydropower development will depend on what changes are made to the existing impoundment and how it is operated. The proposed installation of hydropower generation facilities at Otter Brook Lake would involve increasing the pool level to elevation 715 feet NGVD. This would increase the pool surface area by 78 percent to 125 acres. With such a large increase, much currently vegetated land would be inundated. Thus, detailed studies to determine the amount of reservoir clearing required to maintain optimum water quality conditions must be conducted as the study progresses.

#### Aquatic Vegetation

A 12-foot increase in the pool depth above the winter pool for hydropower development would inundate emergent aquatic vegetation along the reservoir perimeter. The daily fluctuations would limit reestablishment of the emergent vegetative habitat until the newly inundated and fluctuating pool slopes are permanently established. The reservoir basin configuration is steep enough so that no significant development will occur under natural conditions. A gradual shift from terrestrial vegetation to aquatic will occur in the newly defined pool area.

#### Fisheries

The addition of hydropower could result in the loss of cold water fish reproduction sites at the upstream end of the reservoir. The increased depth accompanied by the small daily fluctuation would slough off soil which would silt in the nesting and nursery areas of bass and other species that depend on shallow clear water for reproduction. Further studies would be required to determine to what extent the loss of the shallow water breeding grounds would have on fishery resources and what resulting changes or shifts may occur in numbers and types of species.

## Aquatic Wildlife

Inundation of the wetland vegetation in the reservoir by the proposed increase in pool depth would cause a loss of cover, food, nesting habitat for amphibians, waterfowl and aquatic furbearers that may frequent the area. The lack of a suitable habitat until the new inundated slopes stabilize could require some form of mitigation.

## Terrestrial Vegetation

Raising the pool seasonally 14 feet above the summer pool level for hydropower operations would inundate approximately 60 acres of terrestrial vegetative cover types along the perimeter grasses, shrubs, some of the trees such as hemlock, sugar maple, white pine, yellow birch and american beech would have their roots submerged in part which could result in die back of these species. This may require removal of individual trees to avoid a buildup of debris within the reservoir.

Increasing the pool elevation would raise the seasonal groundwater elevation adjacent to the shoreline. Changes in soil saturation levels will change the plant species composing the new backshore area to types more tolerant to water.

## Terrestrial Wildlife

Raising of the pool will cause upland and aquatic furbearing mammals associated with the terrestrial habitat to be inundated to be displaced to higher elevations. Most would move and adapt to the new habitat limitations. The extent of impact on these terrestrial species would require further study if future detailed planning continues. Appropriate mitigation measures would be developed and adopted where necessary.

## RESERVOIR REGULATION

Any hydroelectric facilities that may be built in association with the existing project would be subservient to the primary purpose of flood control. All flood control activities would override hydropower generation requirements. Control of the project would be retained by the Division Engineer through the Corps' Reservoir Control Center.

## CONCLUSIONS

Three alternatives to add hydroelectric generation facilities to the existing flood control project at Otter Brook Lake were evaluated. All three alternatives proposed increasing the reservoir pool seasonally 12 feet from to winter pool to elevation 715 feet NGVD. The reservoir pool would be returned to elevation 701 feet NGVD for the summer recreation season.

Alternative 1 and Alternative 2 would locate a powerhouse downstream of the dam and would utilize the existing outlet tunnel as a penstock to divert flows for hydropower operations. For Alternative 1, the powerhouse would contain two equal-sized turbine generator units with a combined installed capacity of 300 kW and would be capable of generating 1,257,000 kWh of energy annually.

Alternative 2 would utilize a powerhouse containing two unequal-sized turbine-generator units with a combined installed capacity of 500 kW and is capable of generating 1,541,000 kWh annually. Due to major civil works costs associated with modification of the outlet works, such as tunnel lining and the construction of a new flood control bypass and gate structure, the average annual cost of Alternatives 1 and 2 would exceed the estimated benefits these alternatives could generate. Since the benefit to cost ratios for Alternatives 1 and 2 are 0.67 and 0.57, respectively, it is concluded that the addition of hydropower as designed in these alternatives is not economically justified.

Alternative 3 would require the replacement of the existing weir upstream of the center flood control gate with a new 35-foot high weir into which a mini-submersible turbine-generator unit would be installed. The installed capacity of this unit would be 117 kW and it is capable of generating 499,500 kWh of energy annually. The benefit-cost ratio for Alternative 3 is 1.13 to 1 and therefore is considered economically justified and warrants further investigation.

#### RECOMMENDATION

The concept of installing submersible turbine-generator equipment in a weir upstream of the flood control gates resulted in an alternative with a benefit-cost ratio exceeding unity. Although the submersible units cannot produce the average annual energy that downstream powerhouses are capable of producing, the lower civil works costs for development and the operational flexibility of the units makes hydroelectric development both technically feasible and economically justified at sites previously considered not worthy of development. I recommend that the Otter Brook Hydropower Project proceed to detailed reconnaissance investigation where an array of technically feasible alternatives can be developed.

#### ACKNOWLEDGEMENTS

This study was conducted by the New England Division, Army Corps of Engineers, under the general supervision of Mr. Joseph L. Ignazio, Chief, Planning Division and Mr. Donald Martin, Chief, Basin Management Branch. Investigations were performed by an interdisciplinary project team. Persons primarily responsible for the contents of this report are: Michael Keegan, project management; Paul Marinelli, hydrology and power estimates; Donald Wood, water quality, John Kennelly and Michael Keegan, design and cost estimates; Joseph Horowitz, environmental conditions; Diana Halas, social analysis and John Wilson, archaeological input.

HYDROPOWER STUDY

OTTER BROOK LAKE, NEW HAMPSHIRE

Attachment to the Reconnaissance Report  
Schedule of Work and Budgetary Data

JULY 1984

Reference ER 11-2-101, Which States That:

BUDGETARY INFORMATION IS NOT TO BE RELEASED  
OUTSIDE THE DEPARTMENT OF THE ARMY

## SCHEDULE OF WORK AND BUDGETARY DATA

### General

During the reconnaissance investigation, both conventional and unconventional hydropower developments were formulated and evaluated at Otter Brook Lake. Two alternatives utilizing standard equipment in a conventional development, namely downstream of the dam, were found to be technically feasible but economically unjustified. An unconventional development utilizing a small submersible turbine-generator installed in weir upstream of the center flood control gate was determined to be both technically feasible and economically justified. A recommendation has been made to proceed to an advanced reconnaissance investigation to evaluate this concept in greater detail and to determine if a feasibility investigation is warranted.

The advanced reconnaissance investigation would examine various types of this relatively new submersible equipment under varying development scenarios to determine the potential of utilizing this equipment to provide cost-effective installation of hydropower generating facilities where conventional facilities have not been justified. It is anticipated that it would require \$105,000 and 12 months to perform this advanced reconnaissance investigation. Estimates of cost for each major element of the advanced reconnaissance investigation are shown in Exhibit 1.

### Appropriation History and Proposed Allocations

To date, \$10,000 has been expended on the preliminary reconnaissance investigation of adding hydroelectric facilities to the Otter Brook flood control project. The estimated cost of the advanced reconnaissance investigation is \$105,000. Detailed funding by fiscal year is as follows:

#### Appropriation History

FY 83	\$10,000 (O&M Money)
Total to Date	\$10,000

#### Proposed Allocations

FY 87	\$105,000
Total	\$105,000



<b>STUDY COST ESTIMATE (PB-6)</b> (\$000) For use of this form, see ER 11-2-220			APPROPRIATION TITLE: General Investigations				NAME OF STUDY Otter Brook Lake Hydropower Study, New Hampshire (Conn. River Basin Auth Reports)	
			CATEGORY Surveys				SUBCLASS Authorization Reports from Level B Studies	
			CLASS Comprehensive Studies					
LINE NO.	SUBACCOUNT		CURRENT COST ESTIMATE				PREVIOUS FEDERAL COST ESTIMATE AND DATE APPROVED  (06/15/83)	REMARKS
	NUMBER	TITLE	RECON- NOISSANCE PHASE	FEDERAL FEASIBILITY PHASE	NON- FEDERAL FEASIBILITY PHASE	TOTAL FEASIBILITY PHASE		
	a	b	c	d	e	f		
1	.01	Public Involvement	-			-	-	
2	.02	Institutional Studies	-			-	-	
3	.03	Social Studies	5			5	5	
4	.04	Cultural Resource Studies	-			-	-	
5	.05	Environmental Studies	5			5	5	
6	.06	Fish & Wildlife Studies	-			-	-	
7	.07	Economic Studies	10			10	10	
8	.08	Surveying & Mapping	-			-	-	
9	.09	Hydrology & Hydraulics Investigations	10			10	10	
10	.10	Foundations & Materials Investigations	-			-	-	
11	.11	Design & Cost Estimates	15			15	15	
12	.12	Real Estate Studies	-			-	-	
13	.13	Study Management	20			20	20	
14	.14	Plan Formulation	10			10	10	
DATE PREPARED 15 June 1984		DIVISION New England			REGION New England			Page 1 of 2
		DISTRICT			BASIN			

<b>STUDY COST ESTIMATE (PB-6)</b> (\$000) For use of this form, see ER 11-2-220		<b>APPROPRIATION TITLE:</b> General Investigations				<b>NAME OF STUDY</b> Otter Brook Lake Hydropower Study, New Hampshire (Conn. River Basin Auth Reports)		
		<b>CATEGORY</b> Surveys				<b>SUBCLASS</b> Authorization Reports from Level B Studies		
		<b>CLASS</b> Comprehensive Studies						
LINE NO.	SUBACCOUNT		CURRENT COST ESTIMATE				PREVIOUS FEDERAL COST ESTIMATE AND DATE APPROVED  (06/15/83)	REMARKS
	NUMBER	TITLE	RECON- NOISSANCE PHASE	FEDERAL FEASIBILITY PHASE	NON- FEDERAL FEASIBILITY PHASE	TOTAL FEASIBILITY PHASE		
	a	b	c	d	e	f		
1	.15	Report Preparation	10			10	10	
2	.20	Water Quality	-			-	-	
3	.21	Power Marketing Studies	5			5	5	
4	.22	Transmission Studies	-			-	-	
5	.31	Supervision & Administration	15			15	15	
6								
7		TOTAL	105			105	105	
8								
9								
10								
11								
12								
13								
14								
DATE PREPARED		DIVISION				REGION		Page 2 of 2
15 June 1984		New England				New England		
		DISTRICT				BASIN		